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EDITORIALS.

Architectural Training for Engineers.—A new suggestion comes from Professor Biggin in his paper published in this issue of the BULLETIN, warning the engineers against narrow-mindedness. He recommends particularly the history of architecture as tending not only to assist the engineer in improving the appearance of the structures which he designs but also to keep him out of an intellectual rut. We hear a great

deal about culture for the engineer and many subjects are offered as of excellent cultural value. Architecture seems to combine utility and cultural value and should be a popular "elective" in technical courses.

Improvement in Laboratory Instruction.—At the Boston meeting several committees were appointed to make suggestions regarding details of instruction, details which would save the repetition of unnecessary experiments in the design of equipment. These committees were the outgrowth of the special sessions devoted to the discussion of instructional problems in the several branches of engineering. The committees have not yet begun to send in their contributions, but in the meantime several practical papers will be printed in the BULLETIN. The first is one by Professor G. W. Lamke dealing with a useful machine for the electrical laboratory. Members of the Society can help the committees by sending in contributions of this kind.

The New Land Grant College Association.—Last January a new educational association was formed for the purpose of furthering the interests of the land grant colleges, with Dean J. P. Jackson as president. Other well known members of this society fill important positions. The new association does not plan to duplicate in any way the work of the Society for the Promotion of Engineering Education and it will confine attention entirely to the special problems of the land grant colleges.

Our Column of Humor.—The revised dictionary of mechanical engineering printed in this issue of the BULLETIN is out of the usual line of papers published under the auspices of the Society. It is well, however, for the teacher to get the student's point-of-view in regard to the instruction furnished him. Hence this collection of answers to examination questions, selected by one of our members, cannot fail to be enlightening. As the essence of humor is incongruity, these answers meet the requirements in that direction. It is interesting also to analyze the answers to learn wherein the writers missed the points made by the teachers.

APPPLICANTS FOR ADMISSION.

ANDROS, S. O., Mining Engineer and Field Assistant, University of Illinois, Urbana, Ill. 1913
GLEASON, W. A., Instructor in Civil Engineering, University of Washington, Seattle, Wash. 1913
STEVENS, J. FLOYD, Instructor in Electrical Engineering, University of North Dakota, University, N. D. 1913

LETTER TO THE EDITOR.

SECRETARY S. P. E. E.,

Dear Sir: You may be interested to learn that in reply to my note which you placed in the BULLETIN, asking about thesis requirements in technical schools, I have received two answers.

Director Arthur J. Rowland, of the School of Engineering, Drexel Institute, sent a catalogue and letter showing that for their three-years' course the thesis is omitted. Professor Phelon, of the electrical engineering department, Worcester Polytechnic Institute, sent a catalogue and a letter stating that, subject to approval, elective courses may be substituted for thesis in that department of the Institute.

The faculty of the Engineering School at Tufts voted (November) that the head of any major department shall have authority to substitute on any student's program some other subject in place of thesis.

Yours very truly,
CHAS. H. CHASE.

TUFTS COLLEGE,
March 4, 1913.

AMERICAN ENGINEERS IN TOUR OF GERMANY.

To foster a broader professional spirit between America and Germany, about two hundred of the most prominent mechanical engineers of the United States will go to Europe this summer to attend the 54th Annual Meeting of the *Verein Deutscher Ingenieure* in Leipzig and to inspect the educational and industrial establishments of Germany. The party will

sail on June 10 on the Hamburg-American line steamship *Victoria Luise,* one of the largest and most superbly appointed cruising steamer afloat. Many friends of the engineers are also planning to sail on the steamer and will probably compose the entire passenger list. The official party will consist of two hundred members of The American Society of Mechanical Engineers, accompanied by one hundred ladies.

The program will include many features of interest. On arriving in Hamburg on June 21, the great shipyards will be visited. The party will then proceed next day by special train to Leipzig. Here the King of Saxony will welcome the visitors and the *Verein Deutscher Ingenieure* will tender an official reception at which the President of The American Society of Mechanical Engineers, Dr. W. F. M. Goss, Dean of the College of Engineering of the University of Illinois, will make the principal address. The party will leave on June 25 for a tour of industrial Germany, visiting Dresden, Berlin, Cologne, Düsseldorf, Frankfurt, Heidelberg and Munich, including a trip up the Rhine. Independence Day will be celebrated at Frankfurt under the auspices of the American Embassy.

PERSONAL NOTES.

Alexander D. DuBois, assistant professor of electrical engineering, Purdue University, has resigned on account of ill health. He went to Purdue a year and a half ago from Cornell University. A graduate of the University of Illinois in the class of 1899, Mr. DuBois was in practical work for nine years before taking up teaching. Mr. DuBois's temporary address is, 327 S. Gledwood Ave., Springfield, Ill.

Dr. C. A. Lory, president of the Colorado Agricultural College, has recently been made a member of the advisory board of the 1915 pageant to be held in Denver, Colo.

Ralph L. Parshall has resigned as assistant professor of civil and irrigation engineering at the State Agricultural College of Colorado, and is now with the U. S. Department of Agriculture, connected with Irrigation and Discharge Investigations, headquarters at Fort Collins, Colo.

Arthur H. Blanchard, professor of highway engineering, Columbia University, has been appointed by Governor Sulzer a member of the Advisory Commission on Highways for the State of New York.

The honorary degree of doctor of science was conferred upon John Price Jackson, dean of the School of Engineering, The Pennsylvania State College, by the University of Pittsburgh, on the occasion of the celebration of the 126th anniversary of the granting of the first charter by the legislature of Pennsylvania.

Charles W. Gremple, until recently instructor in mechanical drawing, University of Pennsylvania, is now editor of *Condensed Catalogues*, a publication of the American Society of Mechanical Engineers, 29 West 39th St., New York, N. Y.

PUBLICATIONS RECEIVED.

A. S. M. E. Year Book, 1913.—Containing lists of the members of the American Society of Mechanical Engineers arranged both alphabetically and geographically, and also the affiliates in the Gas Power Section and in the Student Branches. Beside the membership lists, constitution, by-laws, list of officers etc., the Year Book contains a full page picture of Dean W. F. M. Goss, president of the society, and smaller pictures of the other officers and members of the council.

The Throop Idea, by James A. B. Scherer, president of Throop Polytechnic Institute. This short paper which appeared as a supplement to the Institute Bulletin for January, 1913, expresses as the key note of their educational system that "Throop believes that the medieval curriculum devised for the production of 'gentlemen of leisure' and imported into our colleges from aristocratic England should give way to a training with usefulness at its core and ornament on its fringe instead of the reverse."

The American Mathematical Monthly, Vol. XX, No. 1. The editors, in speaking of the many problems of instruction that should be widely disseminated and discussed, speak of the work of Professor E. V. Huntington and the committee on engineering mathematics of which he was chairman, as the most general and sustained work in that direction that has been accomplished. The editors propose to open the columns of the magazine for articles and discussion on the pedagogical side of the teaching of mathematics.

Stone, Vol. XXXIV., No. 3. A monthly magazine "Devoted to the Quarrying and Cutting of Stone for Architectural Uses."

Attitude of Labor Towards Scientific Management, by Hollis Godfrey, Sc.D. A reprint from *The Annals*, November, 1912. The writer shows clearly the differences between scientific management in a shop and the older forms of management and concludes that the attitude of the worker toward scientific management is one of, "Cordial appreciation of the opportunities given them by that science, hearty willingness to cooperate in the development of that science, thankfulness that a freer, broader, finer life will be open to their children because the science of management has come into being."

The New Education, Vol. IV., No. 5. Bulletin of the Agricultural and Mechanical College, published the 1st and 15th of each month by the college, at Stillwater, Oklahoma. Sent free upon request.

On the Shores of the Pacific and *Popular Information*. Profusely illustrated booklets devoted to the furtherance of the Panama-Pacific International Exposition of 1915.

The Iowa Engineer, Vol. XIII., No. 5. Containing among others, an article on Storage Battery Operation and Maintenance, by Charles A. Hobein.

Bulletin, No. 4, Nov., 1912—Feb., 1913, of the Boston Coöperative Information Bureau. "A voluntary association of persons and organizations for mutual assistance in the ascertainment of sources and supplies (generally local) of information, whether these exist in printed or written form, or simply as mental equipment, and whether rendered available by purchase, by loan or by gift." For further information address the Secretary-Treasurer, Mr. G. W. Lee, 147 Mills St., Boston, Mass.

DICTIONARY OF MECHANICAL ENGINEERING.

REVISED.

Steam lead.

When you have steam lead then the valve leads the piston.

Steam lead is the amount the valve must move to begin to move the port.

The lead is the amount that the steam is ahead of the opening of the valves.

Steam lead is the pipe which carries the steam from the boiler to the engine.

British thermal unit.

The B. T. U. is the heat required to raise one sq. ft. of water through one degree Fahrenheit.

The British Thermal h. p. is equal to h. p./746.

Calorific power.

Calorific power is the ability of a conductor to transfer heat.

Calorific power is the power that is contained in the water due to the heat contained therein.

Horse-power.

I. h. p. is the h. p. of an engine in starting.

Boiler h. p. $= PV/33000$ when $V =$ volume of steam space and $P =$ pressure of steam.

Boiler h. p. is the h. p. a boiler will produce per hour when burning 30 pounds of coal per minute per square foot of grate surface.

Advantages of the compound steam engine.

Steam is reduced to lower temperature and is therefore easier to condense.

The steam is lower in pressure when exhausted and a larger area of card can be gotten per pound of coal used.

Not so much jar in stepping down the pressure in a compound engine as in a single cylinder engine.

You use steam non-expansively.

Methods of smoke prevention.

Preheat the feed water so as not to chill the gases.

The exhaust head may take up the objectionable matter such as carbon.

Using forced feed draft forces the smoke up the chimney.

Using two sets of grates, the draft comes down the chimney.

Carry the stack to a great height. This will carry smoke to great height and the larger particles of soot will become cool before making top of stack and will drop. The finer particles will float off in the upper air currents.

Pumps.

A duplex pump is one having two inlet and two exhaust valves.

An outside packed plunger pump is one that has an opening into which a fellow can get to pack the plunger without taking the pump apart.

Condensers.

A barometric condenser simply changes the exhaust steam into water by having the water come into a place at atmospheric pressure.

In a barometric condenser the steam is led out through the power house and up a long high pipe. The steam on being cooled condenses and the water falls down the pipe due to the fact that a column of water over 30 feet can not be held up against atmospheric pressure. The tumbling of the water down through the steam helps to cool it off and the condensed water is caught in a trap at the bottom and then led to the feed water heater. An enlarged top also allows the steam to expand, thereby raising the boiling point and carrying steam to condense.

Stephenson link motion.

To the eccentrics is attached two links which slide in a radial slot. As the eccentric moves the links travel up and down in the slot. The motion of one eccentric closes the valve and the other opens it.

Steam turbines.

The two types of turbines are impulse and back-acting.

THE EFFICIENCY PRINCIPLES OF TECHNICAL EDUCATION.*

Abstract of a paper by

JULIAN C. SMALLWOOD,

Associate Professor of Experimental Engineering, Syracuse University.

While it is recognized that the technical school offers an opportunity for the application of efficiency principles, it has been argued that it would be impossible to put an educator on an efficiency basis, because of the differences in treatment required by different students and because of the difficulty of obtaining a satisfactory standard for measuring the product.

Any scientific basis of measurement of the educational processes must proceed from their correct evaluation. It is necessary therefore first to consider the purpose of the engineering schools. While they aim to make the student familiar with certain facts and principles, and to develop some manual dexterity in certain mechanical processes, these are only primary in sequence. The schools seek to produce men who, by their trained intelligence, can apply those processes of reason and judgment based upon knowledge, which entitle them to the name of engineers.

The difficulty of judging the product may be one reason why engineering schools base the estimate of their own efficiency on examinations requiring of the student, memory—not reason. This, however, should not be. It is not what the student learns that is vital, but what he is able to return with the assistance of the knowledge gained. The capitalist puts out money to work and expects money in return. He would be dissatisfied were he to receive merely the principal, yet in

* The original paper by Professor Smallwood appeared in *The Engineering Magazine* of March, 1912.

most schools a beggarly sixty per cent. of it is considered an adequate return. The capitalist would rightly consider the efficiency of such a transaction zero.

With this understanding of efficiency, we are obliged to concede that the ordinary lecture system is of zero value in that it requires of the student little or no mental activity. At the best, he only absorbs facts, and that with the minimum of effort. An occasional examination for the return of these facts is the harvest of this system of education, a system that puts the student on the intellectual plane of a parrot.

The ideal of education should be the imparting of facts in such a way as to develop to its maximum the student's power to apply them. He must therefore have practice at solving problems and answering thought-provoking questions, not merely questions concerning the contents of a book; with this important addition, that his answers must be intelligently criticized and that each new question must elicit a properly directed train of thought.

We see, then, that an educator's usefulness may not be measured by the length of time he talks or by the number of students he can seat within earshot, but by the time given by the students in reciting to him in such a way that their answers may be criticized. This of necessity ignores the quality of the product. You can not make a silk purse out of a sow's ear, but you can improve both with the same degree of efficiency.

To put these facts mathematically, let us symbolize the number of students taking a course by the letter N, and by H the average number of hours a week devoted by each in reciting under active criticism. Then the useful work per week of the teacher is

$$N \times H.$$

Let us apply this rule to a concrete example. In a three-hour-a-week course the students recite one at a time, the rest of the class being expected to follow the recitation and its criticism. The recital of each student averages twelve min-

utes, so that five are heard in one period. Assuming fifteen students in the class, the value of N is twelve minutes a week or one fifth hour. The teacher's work therefore may be represented by

$$15 \times \frac{1}{5} = 3.$$

This ignores as it should the benefit to be derived by any student in following the recitation of another. No one whose duty does not make it imperative can be depended upon to follow with attention the recitation of the ordinary student. From personal observation, I may say that it is generally the practice for most of a class taught in this way to sleep mentally or at best to occupy themselves with wandering subjects. So the estimate of one-fifth of an hour a week is the only safe one.

It is apparent that the efficiency of this method remains the same no matter what the number of students, for an increase of N diminishes the value of H, the product remaining the same unless we can increase the number of students reciting at a time. This may be done by propounding the same question for simultaneous solution by as many students as can be properly attended. In this way a teacher can keep as many as fifteen students busy continuously during each period, and give them active criticism. In the case of the class previously cited, the teacher's useful work is then $15 \times 3 = 45$.

When it is necessary that class work be interrupted for the purpose of explaining a problem, the value of H, and therefore of the teacher's efficiency, is lowered. It follows that the more able a teacher is to explain clearly and briefly a knotty point, the more efficient is he.

An important part of a teacher's work is the correction of problems, reports, drawings, etc., and this should be included in our estimate of his usefulness. The useful work of the teacher is not proportional to the time he devotes to this task —for he will be the more efficient the less time he spends correcting each paper—but upon the average time *required from*

each student to do the mental work represented by the paper, this time being the value of H. It can be ascertained reasonably accurately by investigation. The product of N and H again is the measure of the teacher's usefulness, the value of N being the number of students whose graphic work receives criticism. This may increase as the average time for the correction of papers diminishes.

This estimate, however, is faulty in that it is impossible to be sure that all the students will honestly and independently take any particular mental exercise when away from the teacher's surveillance. Almost any student will occasionally follow the line of least resistance and present a copy of his class-mate's work as his own. The only way to be reasonably sure that this will not be done is to assign different problems to each member of the class. This greatly increases the labor of correcting the papers, and the value of N is much reduced while H is made slightly greater.

If the same problem for home work is given to all the members of a class, the product of N and H should be multiplied by a factor less than one to allow for the time apparently but not actually spent. This factor must needs be arbitrarily chosen and, though a makeshift, the resulting quantity more truly represents the one sought.

The same method of measuring applies to drawing room and manual work. Here again we need to multiply the product of H and N by a factor less than one to reduce the quantities to terms comparable with those for class-room work.

In the experimental laboratory we meet with different conditions. It is found necessary to have several students working together, and the result is that one or two furnish the brains and the rest the ornamentation. A dull student may successfully hide his ignorance in the work of a squad. A large part of such work consists of a purely mechanical use of the senses, but this is not the most important part. To obtain the best results it is necessary to exact individual work. Experiments should be assigned as well rounded problems, not as mechanical tasks. The teacher should quiz the

student during the period, ask the significance of the measured quantities, insist upon rough calculation of the results as the data are taken, etc. In this way the teacher should spend all the time available during the period. His useful work may then be represented by $N \times H + N \times H' \times F$, in which N is the number of students, H the average number of hours spent by each in mental work *under the teacher's criticism*, H' the time spent in purely manual work, and F a factor to reduce the two to a common basis.

These measures of an educator's output establish the numerator of a fraction expressing his efficiency. A standard denominator may be estimated by fixing the maximum product of N and H possible with a reasonable expenditure of effort.

To make the standards here set down the fundamental principles of the ordinary technical school would involve an outlay of money for additional instructors and equipment far in excess of its resources. To replace the lecture system by the text-book method would necessitate up-to-date text-books covering all the class-room courses, and these are not always available.

There is some course in each technical school, that differs from the corresponding one given in other schools, because of the personal experiences, hobbies or limitations of the teacher. Naturally it is found difficult to secure a text-book covering the special subject matter of the course. Furthermore the exigencies of modern advertising have made it seem desirable that the schools cater to popular fancy and offer faddish courses. These may be all very well in their place as electives, but they should not be made requisite for a degree covering a broad engineering field. Aside from these abnormal differences, one is struck by the fact that no two curricula, leading to the same degree, are the same; and that in very few cases do corresponding courses in two schools follow identical lines.

It seems that a standardization of engineering curricula would be an eminently desirable object. Let the technical schools decide upon and rigidly define the proper courses of

study leading to the various degrees. As a detail of this work, the selection of standard text-books and equipments would follow.

In conclusion, let me briefly answer the argument that to put education upon an efficiency basis would stifle the individuality of the teacher. In many cases this would be the effect, but I am inclined to believe that it would be desirable. The technical teacher is not an artist or a poet who is obliged to await divine, though unsystematic inspiration. He is a workman whose tool is his brains; he should use it with the same method with which a good workman handles tools of steel. He must not fall into the common error of people who blame their lack of method, really due to sloth, upon temperamental disability. He should subdue his own ego in order to train and develop the individuality of others, for this is the aim and end of education.

SCIENTIFIC RANKING SYSTEMS.

BY WINSLOW H. HERSCHEL,

Associate Professor of Mechanical Engineering, University of Maine.

It must be assumed, in the first place, that by the customary examinations, recitations and other methods the instructor is able to determine the relative ability of his students. The problem still demanding solution is what percentage of these students should receive each of the various grades.

There is need of both an absolute and a relative standard. It is not necessary that the highest mark should always be given out; it may be withheld if no candidate seems to deserve it, just as is often done in prize competitions. At Reed College not more than one man in 400 or 500 is expected to receive the highest or the lowest grade;* nor is it necessary that any one in a small class should fail, as the poorest student in a small class one year may be as good as an average student another year. With a large class there is less possible variation from year to year, and it is but natural that some should fail.

The Missouri and other similar systems of grading are based on the curve of probability, which has the equation $y = y_0 \frac{-x^2}{2\sigma^2}$ where y is the ordinate at any distance x from the middle, maximum ordinate y_0 and σ is the standard deviation.† The equation may be simplified by taking y_0 and σ both equal to one, and then if $x = 3$, $y = 0.01111$; and if $x = 4.8$, $y = 0.00001$. It will be seen that y soon becomes negligible, though theoretically it never reaches zero. Roughly, the shape of the curve is that of a gendarme's hat,

* See article by President Wm. T. Foster, in *Science*, June 7, 1912, p. 887.

† See "An Introduction to the Theory of Statistics," by G. Udny Yule, 1911, p. 298, or some similar work.

and one with a seven-inch base and maximum height of six inches may be obtained very approximately as follows: With a center on the middle ordinate, 5⅝ inches above the X axis, and with a radius of ⅜ inch, describe a semicircle. Erect a perpendicular at each end of the base. With centers on these perpendiculars, 1¾ inches above the X axis, and a radius equal to 1¾ inches, describe arcs tangent to the base. Draw sloping lines tangent to the semicircle and to the arcs.

When this normal curve of probability is used as a basis for grading systems, equal abscissas represent equal differences of ability or of grading, and areas included between the curve, the X axis and two ordinates represent percentage of the whole number of students graded, whose ability lies between the abilities indicated by the limiting ordinates. The first difficulty experienced in using this curve is due to the indefinite length of the base line. This is frequently taken equal to 6, on the ground that y is practically zero when x is equal to plus or minus three. It is customary in using the curve for other purposes to divide the area in such a manner that the middle of three parts is equal to the sum of the other two, or is equal to 50 per cent. of the whole. This method of division, with a six inch base, is the basis of the Missouri system. By dividing each of the two end areas in halves, equal as regards length of base, but unequal in area, we shall have, finally, five areas containing respectively 3, 22, 50, 22 and 3 per cent. of the whole. If, in accordance with the business conception that *A* No. 1 means best, we call the highest grade *A*, and let *E* represent the antithesis of excellent, marks would be distributed in the long run as follows:

A	*B*	*C*	*D*	*E*
3 per cent.	22 per cent.	50 per cent.	22 per cent.	3 per cent.

It will be seen that the division is somewhat conventional or arbitrary, and that the different grades do not cover equal ranges of ability. The probability curve might be divided in other ways, and the other percentages thus resulting could with equal right be adopted and considered as the scientific

system. It seems reasonable that, as far as possible, each grade shall represent an equal range of ability, or be represented by equal lengths along the base of the curve. There are always a few men with much less or much more ability than the bulk of the students, and the difference between any two of these few is much greater than between any two of the rest. If the highest and lowest grades are chosen too far from the average, differences between extraordinary students could be expressed, but the majority would come too close together. It is therefore necessary to locate the extreme grades so that the majority may be readily distinguished, and to consider all students of ability beyond these limits as having either the highest or the lowest grade.

Table I shows the distribution of students in the different grades, obtained by dividing the 10-inch base into from 3 to 26 equal parts. It will be noticed that after there are more than five divisions the number of students in the extreme grades is less than 0.1 per cent. and it would seem unnecessary to reserve a grade which would be so seldom used. But it seems quite possible to preserve equality of range except in the end divisions. For example, if five grades were desired, we might use grades each covering 1.11 inches, and, grouping the three highest divisions together in one highest grade, obtain the percentages:

A	*B*	*C*	*D*	*E*
4.8 per cent.	24.4 per cent.	41.6 per cent.	24.4 per cent.	4.8 per cent.

Or if 10 grades were desired, as at Reed College, we might obtain similarly, with grades having a range of 0.62 inch along the base,

Grade No. ..	1	2	3	4	5	6	7	8	9	10
Per cent. ...	0.6	2.4	7.6	15.8	23.6	23.6	15.8	7.6	2.4	0.6

As an argument for less number of grades, Professor Meyer points out* that because the difference between two students of nearly average ability is so slight, we ought not to

* *Science*, August 21, 1908, p. 243.

use more than five grades for fear of doing an injustice in attempting impossibly fine distinctions. Even if we concede that ten is about the proper number of grades, it would seem that some odd number, as nine for example, would be better than ten, as this would avoid having a division line exactly in the middle, where the difference between individuals is a minimum.

Even if no suitable system of grades can be found in Table I, it does not seem necessary to give up dividing the base line into equal divisions, in order to obtain a system as desired, both in regard to total number of divisions and percentage in the extreme grades. For any number of additional systems may be obtained by using a base of other lengths than the 10 inches here assumed, resulting in different lengths of the separate divisions than those given in the table. Additional systems may also be obtained by the addition of adjacent percentages in Table I, that is by taking divisions just twice as long. This results in the values shown in Table II.

The systems thus far considered are symmetrical, as in the normal probability curve, but this curve does not apply except to individuals selected at random. Now college students are a body of men selected by examination, and to such a group a curve would apply which has been distorted out of symmetry, or, as it is called, "skewed in a positive direction," that is, the peak has been moved toward the lower grades. It is very important to note that the skewing is in just the opposite direction from what would naturally be supposed. A little consideration of the probability curve will show that if the *E* men are eliminated, and the men in the remaining four grades redivided into five grades, there will be more students in the lowest grade than before. Up to the time when school attendance ceases to be compulsory, those who fail to pass are not eliminated, but merely drop back into the lower class and thus do not change the proportion of bright and dull students in the normal distribution. But those who drop out at a later period and go to work may affect the composition of the class, provided their action is due to lack of ability and not to

TABLE I.

SHOWING THE DISTRIBUTION OF STUDENTS IN THE DIFFERENT GRADES, OBTAINED BY DIVIDING THE 10-INCH BASE INTO FROM 3 TO 26 EQUAL PARTS.

Length of Division.	Number of Grade.														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
3.33	4.8	90.4	4.8												
2.50	0.6	49.4	49.4	0.6											
2.00	0.1	15.7	68.4	15.7	0.1										
1.67	0.0	4.8	45.2	45.2	4.8	0.0									
1.43	0.0	1.6	21.9	53.0	21.9	1.6	0.0								
1.25	0.0	0.6	10.0	39.4	39.4	10.0	0.6	0.0							
1.11	0.0	0.3	4.5	24.4	41.6	24.4	4.5	0.3	0.0						
1.00	0.0	0.1	2.2	13.6	34.1	34.1	13.6	2.2	0.1	0.0					
.91	0.0	0.1	1.1	7.4	23.7	35.4	23.7	7.4	1.1	0.1	0.0				
.83	0.0	0.6	4.1	15.6	29.7	29.7	15.6	4.1	0.6	0.0					
.77	0.0	0.3	2.4	9.8	22.7	29.6	22.7	9.8	2.4	0.3	0.0				
.71	0.0	0.2	1.4	6.0	15.9	26.5	26.5	15.9	6.0	1.4	0.2	0.0			
.67	0.0	0.1	0.9	3.8	11.1	21.2	25.8	21.2	11.1	3.8	0.9	0.1	0.0		
.62	0.0	0.1	0.5	2.4	7.6	15.8	23.6	23.6	15.8	7.6	2.4	0.5	0.1	0.0	
.59	0.0	0.1	0.3	1.6	5.1	11.9	19.6	22.8	19.6	11.9	5.1	1.6	0.3	0.1	0.0
.55	0.0	0.3	1.0	3.4	8.6	15.8	20.9	20.9	15.8	8.6	3.4	1.0	0.3	0.0	
.53	0.0	0.2	0.7	2.4	6.2	12.0	18.3	20.4	18.3	12.0	6.2	2.4	0.7	0.2	0.0
.50	0.1	0.5	1.7	4.4	9.2	15.0	19.1	19.1	15.0	9.2	4.4	1.7	0.5	0.1	
.48	0.1	0.3	1.2	3.3	6.8	11.9	16.9	19.0	16.9	11.9	6.8	3.3	1.2	0.3	0.1
.45	0.1	0.2	0.8	2.3	5.3	9.4	14.2	17.7	17.7	14.2	9.4	5.3	2.3	0.8	0.2
.43	0.2	0.6	1.7	3.9	7.4	11.7	15.8	17.4	15.8	11.7	7.4	3.9	1.7	0.6	0.2
.42	0.6	1.3	2.9	5.8	9.8	13.3	16.3	16.3	13.3	9.8	5.8	2.9	1.3	0.6	
.40	0.5	0.9	2.2	4.5	7.8	11.5	14.7	15.8	14.7	11.5	7.8	4.5	2.2	0.9	0.5
.38	1.0	1.8	3.4	6.1	9.8	13.1	14.8	14.8	13.1	9.8	6.1	3.4	1.8	1.0	

financial or other troubles which are independent of scholarship. The following table showing the distribution in percentage of grades given at Harvard during two academic years indicates a decided tendency to an increase in the percentage of high marks as the courses become more advanced.

Course.	No. of Marks.	*A*	*B*	*C*	*D*	*E*
Elementary	8,969	7	20	42	21	7
Intermediate	2,456	12	28	37	13	4
Advanced	476	36	38	13	2	2

Table III shows the percentage of the original class of students which would remain at the end of each of 10 successive years, if a fraction, ranging from 10 per cent. to ½ per cent. dropped out each year. Table IV shows how these

TABLE II.

ADDITIONAL SYSTEMS OBTAINED BY TAKING DIVISIONS TWICE AS LONG AS IN TABLE I.

Length of Division.	Number of Grade.							
	1	2	3	4	5	6	7	8
2.00	2.3	47.7	47.7	2.3				
1.67	4.7	45.3	45.3	4.7				
1.43	1.6	21.9	53.0	21.9	1.6			
1.25	3.0	23.4	47.2	23.4	3.0			
1.11	1.3	12.0	36.7	36.7	12.0	1.3		
1.00	2.3	13.6	34.1	34.1	13.6	2.3		
.91	1.1	7.6	23.6	35.4	23.6	7.6	1.1	
.83	1.8	8.7	23.1	32.6	23.1	8.7	1.8	
.77	1.0	5.2	15.9	27.9	27.9	15.9	5.2	1.0

losses would skew the symmetrical curve, with one inch divisions, of Table I, the increase in the proportion of students in the lower grades increasing with increase in the percentage of loss.

Writing in 1911, President Foster suggested, for five grades,

A	*B*	*C*	*D*	*E*
2 per cent.	18 per cent.	50 per cent.	24 per cent.	6 per cent.

From our tables, this amount of skewing would be caused by a

TABLE III.

SHOWING THE PERCENTAGE OF CLASS REMAINING AT THE END OF EACH OF TEN SUCCESSIVE YEARS, IF THE FRACTION GIVEN IN THE FIRST COLUMN IS DROPPED EACH YEAR.

Per Cent. Dropped.	No. of Year.									
	1	2	3	4	5	6	7	8	9	10
10	90.0	81.0	72.9	65.6	59.0	53.1	47.8	43.0	38.7	34.8
9	91.0	82.8	75.3	68.6	62.3	56.7	51.7	47.0	42.8	38.9
8	92.0	84.7	77.8	71.6	65.9	60.7	55.7	51.3	47.2	43.4
7	93.0	86.5	80.5	74.8	69.7	64.8	60.2	56.0	52.2	48.5
6	94.0	88.4	83.1	78.2	73.5	69.1	65.0	61.1	57.5	54.0
5	95.0	90.3	85.8	81.5	77.5	73.6	69.8	66.4	63.1	59.9
4	96.0	92.3	88.5	85.0	81.6	78.3	75.2	72.2	69.2	66.5
3	97.0	94.2	91.3	88.5	85.8	83.3	80.8	78.4	76.0	73.8
2	98.0	96.0	94.2	92.3	90.4	88.5	86.8	85.1	83.4	81.8
1	99.0	98.0	97.0	96.0	95.0	94.0	93.1	92.2	91.3	90.4
½	99.5	99.0	98.5	98.0	97.5	97.0	96.5	96.0	95.6	95.1

loss of less than half of one per cent. per year. The scheme adopted at Reed College, omitting the highest and lowest grades which are seldom used, has the following eight grades:

Grade No.	2	3	4	5	6	7	8	9
Per cent.	5	10	15	20	25	15	6	4

TABLE IV.

SHOWING SKEWED DISTRIBUTION OF GRADES, IN PER CENT., IF THE FRACTION GIVEN IN THE FIRST COLUMN HAS BEEN DROPPED.

Per Cent. Dropped.	No. of Grade, No. 1 Being the Highest.									
	1	2	3	4	5	6	7	8	9	10
0.0	0.0	0.1	2.2	13.6	34.1	34.1	13.6	2.2	0.1	0.0
0.1	0.0	0.5	3.4	13.2	27.3	30.5	18.2	5.9	1.0	
0.5	0.0	0.3	1.9	8.2	20.2	29.2	24.2	12.2	3.8	
1.0	0.0	0.3	1.6	7.4	18.4	28.1	25.6	14.1	4.5	
3.0	0.0	0.2	1.0	5.0	13.6	24.2	27.2	19.8	9.0	
5.0	0.0	0.1	0.9	3.9	11.5	22.2	27.2	22.2	12.0	
10.0	0.0	0.1	0.6	2.9	8.7	18.2	26.0	26.0	17.5	
20.0	0.0	0.1	0.4	1.9	6.0	14.4	23.6	28.8	24.8	
30.0	0.0	0.4	1.4	4.7	11.6	22.0	29.6	30.3		
40.0	0.0	0.3	1.2	3.8	10.3	19.7	30.3	34.4		
50.0	0.0	0.2	1.0	3.4	8.8	18.4	30.0	38.2		
60.0	0.0	0.2	0.8	2.5	6.5	15.0	26.5	48.5		
70.0	0.0	0.3	0.7	2.4	7.0	15.7	28.6	45.3		

Here also there is a skewing of the curve to allow for the influence of selection, though less than would be expected from the numbers who drop out each year.

The explanation seems to be that examinations are not an effective means of determining ability. Professor Cattell goes so far as to say* that students who pass entrance examinations "with the lowest grades are as likely to do well in college as those having much higher grades. Those rejected would probably do equally well."

While it is difficult if not impossible, without more data than at present available, to adopt a curve that shall depart from the normal by just the right amount, it is none the less desirable that some curve should be adopted. Any reform which merely concerns methods of marking is of little value if it leaves the question of preparation of the examination untouched. The great advantage of the Missouri system is that both preparation and marking are controlled. Perhaps it would be radical enough as a first step to adopt the symmetrical or normal curve, and then adopt a skewed curve later if it seemed desirable. In any case there seems to be no satisfactory reason why an instructor should habitually give very many more high marks than called for by the normal curve, because that calls for a maximum, as any skewed curve would require less.

Another advantage of the Missouri system is that any instructor may adopt it for himself, without waiting for concerted action. It is apt to prove conducive of considerable thought, if an instructor calculates the percentages of the different grades which he gives on the average, compares them with the normal percentages, and then tries to explain the difference.

* *Popular Science Monthly*, February, 1905, p. 367.

ARCHITECTURAL TRAINING FOR ENGINEERS.

BY FREDERIC BIGGIN,

Professor of Architectural Engineering, Oklahoma A. & M. College.

Some time after the Franco-Prussian war, at a diplomatic dinner party in one of the European capitals, the French ambassador was speaking warmly of the artistic capacity of his countrymen. He had just declared that the French could take anything, of even the meanest character, and make it beautiful, when a grizzled old German general, tearing a handful of stubby hairs from his beard, threw them on the table, and in a disgusted voice demanded of the ambassador that he have them made "beautiful." The latter took the short gray hairs with a smile, and placed them carefully in his pocket-book. A day was appointed in the near future when the company should again assemble, to view and judge the result. Time passed. The dinner party gathered, and with the cigars the general was handed by the waiter, a small box carefully wrapped. On disclosing the contents, they proved to be a copy in gold of the German eagle, most beautifully modeled. In its talons the bird held one of the general's hairs, but from the ends hung two tiny golden balls, inscribed respectively: "Alsace," and "Lorraine." From the eagle's beak floated a streamer on which was the legend: "You hold them, but by a hair." The ambassador had won.

As illustrated by this story, France has taught the world at least one great lesson: "To construct everything with artistic effect." Years ago, when her sons built the Eiffel tower, instead of resting content with making it the most ambitious structure of that day, they created it also an object of graceful lines and detail. To the American, perhaps, in particular, the Alexander III. and other magnificent bridges crossing the Seine, are like a draught of cold water on a scorching August

day. They call to the traveller to pause, and feast his eyes on their beauty. For all this, such engineering structures perform no less well the more prosaic task, of bearing persons and vehicles over the river. In Paris, therefore, we are not surprised to find the greatest school in the world for instruction in design. Known as the *"Ecole des Beaux Arts,"* it is literally a "School of the Fine Arts."

All things obey the laws of "cause and effect." Whether the passion of the French nation for making objects of utility beautiful, is due to the widespread influence of such a school, or whether schools of this kind owe their existence to an instinct and craving born in the race, is hard to tell. Certain it is, however, that the artist, the architect, and the architectural engineer are honored in France as nowhere else on earth. A graduate of the *Ecole des Beaux Arts* is assured of government work, and starts his professional life with a prestige that renders life very far from the uncertain path of thorns one sometimes finds it in other countries. "What are the greatest needs of the American to-day?" is often asked. Without hesitation one might place in the list: "A great National School of the Fine Arts," modeled on that at Paris.

American engineers are among the most skillful in the world. They can construct anything, from the submarine boat that tunnels its way below the surface, to the air-ship that flies above. For general intelligence, for clever solution of difficult problems, they can be depended on with confidence to maintain always, and everywhere, the supremacy of the white race. But perhaps more than all things, the average American engineer prides himself on being "practical." Too often his ideas of beautiful lines, I regret to acknowledge, do not get beyond those of an I-beam. He is usually content to call a job done when the Frenchman would consider it but half-done. So we have bridges that can carry great train loads, reinforced concrete arches spanning seemingly impossible gorges or rivers, and other wonderful structures without number—all soundly built, but absolutely naked of architectural treatment.

Though it is hard to believe, there exist engineers, and sometimes good ones, who glory in that nakedness, who claim that an engineer's time should not be "wasted," in making things beautiful. But God was the first engineer, and He created this world so full of beauty, that unless one has neuralgia, or perhaps an empty pocket-book, it is a pleasure to live in it.

To accomplish the best results in professional life, I believe that *all* engineers should possess a good working knowledge of architectural engineering. The line of demarcation, that once stood, like the "angel with the flaming sword," between engineering and architecture, has almost ceased to exist. Architectural engineering constitutes frequently a large part of the modern engineer's work. Engineers with a knowledge of architecture, architects who understand engineering, are both required for the construction of the great buildings, bridges, and other monuments, which, long after the men of our times have passed on, will remain to tell following generations or even another race, of what metal we were made.

But what special advantage, you may ask, will a training in architectural design be to a mechanical engineer? The man who has taken such a course will design his machines along artistic lines, instead of crude ones; he will of course continue to use the greatest amount of metal where it is required for strength, but he will also not hesitate to place extra metal wherever this will add to the looks of his product. Considering the latent sense of the beautiful in all of us, will not the average buyer, think you, be attracted by the machine that appeals to this sense? And a working knowledge of mill and factory construction, slow-burning, fireproof, and other sorts,—will it not be of aid to the designer and manufacturer alike, and help toward a better understanding of the buildings into which their machines are to go, and by which they must be supported? For example, certain machinery produces heavy vibration in a given direction. To house such properly, requires a specially built structure having in both walls and floors great mass, to take up the vibratory effect. Lacking

this, machines of this type must be placed on the ground floor. In one case under the writer's observation, an engineer, ignorant of building construction, placed similar machines in the top story of a factory having but thirteen-inch walls and no buttresses, with the result that he almost knocked the structure down.

So likewise an electrical engineer, as the mechanical brother, will not only find a readier and more profitable sale for his machinery when designed along good lines, but a knowledge (and it cannot be too thorough) of the planning and construction of buildings, and the relations of systems of wiring, lighting, heating, and power to buildings, will prove absolutely essential for his success.

As for the civil engineer, what a world of trouble might have been prevented, in those early days of modern fireproof building, had the civil engineers who designed the steel or concrete framework, understand better the relation that must exist between that framework and the exterior and interior finish of the buildings. Many a mechanic tarnished his church record under the necessity of securing the facing of stone, terra cotta or brickwork, to columns and spandrel beams that refused to accommodate them, while some of the famous architects of that time, who planned and superintended the construction of these buildings, are, it is regrettable to record, notorious for having become irreligious persons.

There is a grave danger to which all technical graduates are exposed, that they may get out of touch with the throbbing of the great world. That they may become machines themselves, tied to the rails like a locomotive, seeing nothing, appreciating nothing outside of their own professions. Reading regularly some great metropolitan newspaper, will serve to counteract that tendency. Attending the lyceum and other lecture courses, will also help. But the most efficient results are obtained, when one takes up the study of some subject of general interest which has little or no direct bearing on the technical course. Such a subject is the history of architecture. Broader in its scope than general history, the history of

architecture shows by painstaking and intelligent examination of the buildings and other monuments left behind them how the nations of the earth have been born, grown up, and developed in national spirit, religion, and power. It shows how they have executed wonderful works as a result of that development, and then, when their time was ripe, when indulgence in luxury and uncurbed passions had rendered them soft, and their arms weak, they have been submerged by stronger, more virile races, and gone back into the mists from whence all came. Thus are worked out the unchangeable laws of cause and effect.

Regardless of sex or vocation, one branch of architectural design must appeal to all,—the planning of residences. Man, woman, and child, each one of us must live in some sort of a house. Where it has been well planned and constructed, we reap the benefits in comfort and health; otherwise we pay for our lack of knowledge in discomfort, in huge doctors' bills and sometimes in the loss of the lives of our loved ones. As a strictly business proposition therefore, it pays to understand the subject of house building, to know what goes to the making-up of a healthful and comfortably planned dwelling. Were this knowledge more general, perhaps half of the rented houses in the average town would be without tenants. They would be avoided as one does poisoned water, and the owners would remedy the defects, or pull them down and build modern dwellings in their place.

Of every profession it has been said that the ranks are crowded. This may be true of the older lines of work, but the architectural engineer is a creation of the last twenty years, and the field opened before trained men and women is wide, and has many paths. The offices of all large modern architects have an architectural engineer in charge of the constructive side of the work. The great construction companies, for which this century is famous, must have architectural engineers for the same purpose. As a contracting engineer, the architecturally-taught man possesses a tremendous advantage over the average contractor, both in the capacity to accom-

plish good work, and the making of money. When equipped with an efficient training in design, in the development of decoration, and the use of color, the architectural engineer may practice successfully the profession of architecture, either alone or in conjunction with others.

Whatever line of effort be selected, architectural engineering offers a broad and attractive field to the individual who is contented with nothing short of the best preparation, who takes himself seriously and depends on hard work for success.

MATHEMATICS IN THE ROYAL POLYTECHNIC INSTITUTE AT HANNOVER.

BY A. R. CRATHORNE,
Associate in Mathematics, University of Illinois.

The "technische Hochschule" in Hannover is not the largest, oldest nor the best known engineering school in Germany, but the work done there is of the highest grade and quite typical of German technical schools. Especially is this true of the work of the mathematical departments and of departments closely allied to mathematics. During the last semester the writer visited this "Hochschule" and was given every opportunity to see the work in mathematics in actual progress, and incidentally to compare the required courses in mathematics with the corresponding courses given in our American engineering colleges.

A student usually enters this institution after finishing a course in a "Gymnasium" or "Oberrealschule." It is rather difficult to compare these German secondary schools with schools in the United States, but we can say that the young man of nineteen who receives his certificate from either of the above two schools is at least on a par with our average college sophomore. A six-year high school might well be compared with the German "Gymnasium" and a six-year technical high school with the "Oberrealschule." As far as amount is concerned the German student has probably not "taken" more mathematics than an American boy from a good high school, but his work has been more thoroughly done and he is a better mathematician.

The course at Hannover usually takes four or five years to complete and is divided into two parts. After four or five semesters residence the student may take the examination, the so called "Diplomprüfung," for the degree "Dipl.-Ing." (cer-

tified engineer). After two or three more years, one of which must be spent in actual engineering practice, the "Dipl.-Ing," after satisfying certain requirements and writing an acceptable dissertation, may take the examination for the degree "Dr.-Ing." We may say that the course takes five years, including the year in actual practice which often comes just after receiving the first degree.

The entering freshman with the above mentioned training and course before him begins his mathematics with a course called "Höhere Mathemetik I," which consists of six lectures a week, two hours for discussion of problems given for solution, and one hour of review and questions, for those who care to attend. The subject matter is analytic geometry and elementary calculus. The topics taken up last year were:

Coördinate systems; the straight line; systems of two and more straight lines; triangle problems; the circle; the ellipse; the hyperbola; the parabola; transformation of coördinates; theory of conic sections; confocal conics.

The notion of a function; limits; differentials and the derivative; exercises in differentiation; hyperbolic functions; tangents; derivatives of higher orders; Taylor's series and applications; maxima and minima of functions of one variable; differentiation of implicit functions; inverse functions; concavity; points of inflection; curvature; geometrical meaning of an integral; practice in integration; definite integrals; integration by substitution; integration by parts; applications of integration; differential equations of first order and first degree.

In the second semester with the same arrangement of hours comes "Höhere Mathematik II," which covers analytic geometry in space and more advanced calculus. Last year's topics were:

Coördinates in space; projection; plane and straight line in space; sphere and circle; convergence of series; indeterminate forms; functions of several variables; partial and total differentiation; tangents to space curves; tangent and normal planes to a surface; Taylor's series for functions of two variables; maxima and minima of these functions; rectification of space curves; approximations; Simpson's rule; some simple differential equations of second order.

In the third semester comes "Höhere Mathematik III," including:

Transformation of coördinates in space; surfaces of the second order; theory of the complex variable; roots of an equation of the nth degree; asymptotes of plane curves; envelopes; singular points; separation into partial fractions; double and multiple integrals; volumes and surfaces; the integrating factor; differential equations of first order and higher degree; singular solutions; trajectories; differential equations of higher orders; simultaneous differential equations; approximate solutions of differential equations.

During the latter part of his course the student is "advised" to elect other courses in mathematics chosen from a list which varies somewhat from year to year. The student's choice depends upon the kind of engineering he is studying. During the present year the list reads vector analysis, algebraic analysis, calculus of variations, projective geometry, hyperbolic functions. This advice results as one might expect, and probably as originally planned. The students with mathematical leanings elect these courses, usually less than ten per cent. of the class.

The three courses outlined above are required of all engineering students. The architects and chemists take a special four-hour-a-week course for one year called "Grundzüge der höheren Mathematik für Architekten und Chemiker." This is an elementary course in analytic geometry and calculus with many applications.

To compare the content of this required work in mathematics with the content of the corresponding work in the United States is not difficult. The above three courses cover very nearly the work given in the two volumes of "A Course in Mathematics," by Woods and Bailey, a text used in many engineering colleges. Or we may say that the course is very much like the work in mathematics which begins with the second semester of our freshman year and runs through the sophomore and in some institutions is continued into the junior year.

In this country we are wont to think of the German tech-

nical schools as quite given over to mathematics, but on comparing the courses required for their engineering graduates with those in our own colleges we find them to be but little more advanced in content than our own. When we consider the difference in the secondary preparation of the students of the two countries and the maturity of the German freshman, it is to be expected that we should hear more complaint about the difficulty of our mathematical courses than one hears in Germany. If the courses in mathematics at Hannover fit conditions there, perhaps some of us who have work with engineering seniors are right when we think that some of the men have "taken" more mathematics than they have absorbed.

FUNDAMENTALS OF EDUCATION AND THE SPHERICAL-WANT SYSTEM.*

BY F. W. SPRINGER,
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IX.

Money-Life Curves and Education.

Certain phases of the educational, vocational and wage problems can be brought out by the accompanying money-life curves. These curves are intended to illustrate a method of comparing the vocational efficiencies of different classes of people and of different systems of education. Every phase of life, education, health, etc., natural resources, conservation, production, distribution, and consumption, etc., is involved.

Vocational efficiency depends very largely upon the efficiency of the educational system. If students are filled with *ideas* about things quite outside their spheres of activity and are taught subjects for which they have no decisive want, it is quite apparent that the results cannot compare with those resulting from a method by which they learn those things needed and used at the time. This is especially true if the boys are stimulated to high-pressure will and action to apply ideas by their own personal wants. Compelling students to learn facts which are only of artificial interest to them and quite outside of their lives, cannot give very satisfactory results. In the near future, a teacher will be rated by his ability to create an environment which will stimulate the pupils to want to solve problems, rather than by his success in using compulsion and "limits."

A real leader is a man who can induce people to want what

* Continued from March BULLETIN, p. 482.

he wants; a politician is one who pretends to want what he thinks the people will most likely want; and a good teacher must be a leader who can stimulate those wants in a pupil which are consistent with the pupil's stage of development and which will lead to the acquisition of knowledge of use in the present, as well as in the future.

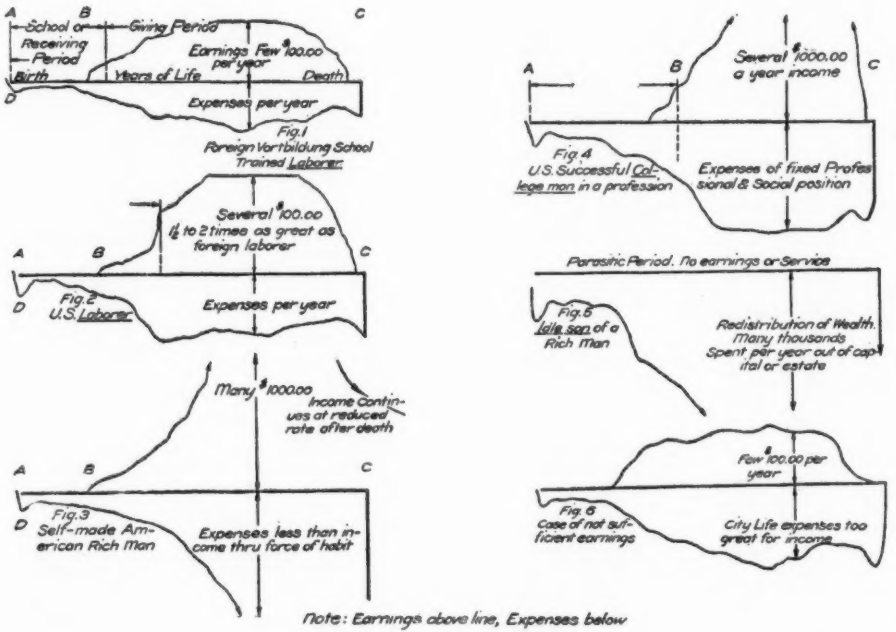
Of all vocational teaching systems for the masses, the fortbildung (continued-education) system seems to be the only one yet devised that satisfactorily increases the efficiency of the common people and, at the same time, lends itself to a vocational system of teaching which should still further increase the efficiency. Further, it permits early marriage.

The highest efficiency in education and vocation demands the formation of useful habits only, under the high driving power of the pupils' own wants, and such other incentives as are necessary to prevent the formation of bad habits. Often one little bad habit spoils the boy's chances of success, hence the formation of good habits, or the acquirement of useful knowledge, must begin at birth.

The first curve is intended to give an idea of expense and income of a foreign laborer, who has attended a "Fortbildung School." It is to be noticed that the "receiving" part, or the school side of his curve, AB, is short, and that the earnings equal the expenses at an early age. If boys in America, learning trades between the ages of fourteen and eighteen, attended a fortbildung school a few hours per week they should be able, on the average, to just about make their expenses. This would cut down the expense curve of the fathers.

The second figure is that of a United States laborer; the third, that of a self-made rich man; the fourth, a college man; the fifth, an idle son of a rich man; the sixth, a shop girl or the like.

The longer the receiving or educational period, AB, in which little or nothing is earned, the greater must be the rate of earning, or the wages, BC, in mature life in order to justify the economic right of the individual to live. It might be a good thing for some of us to plot our money-life curves to


A
B
C
D
School or Receiving Period
Birth
Giving Period
Years of Life
Death
Earnings Few $100.00 per year
Expenses per year
Fig.1 Foreign Vortbildung School Trained Laborer
Several $100.00 ½ to 2 times as great as foreign laborer
Fig.2 U.S. Laborer
Many $1000.00
Income continues at reduced rate after death
Fig.3 Self-made American Rich Man
Expenses less than income thru force of habit
Several $1000.00 a year income
Fig.4 U.S. Successful College man in a profession
Expenses of fixed Professional & Social position
Parasitic Period. No earnings or Service
Fig.5 Idle son of a Rich Man
Redistribution of Wealth. Many thousands Spent per year out of capital or estate
Few $100.00 per year
Fig.6 Case of not sufficient earnings
City Life expenses too great for income

Note: Earnings above line, Expenses below

MONEY-LIFE CURVES.

see how long we should live in order to justify the expenditures made by parents, the state and ourselves.

It is evident that these money-life curves may fall far short of representing the value of a man to his country. The rich man may be a positive detriment and the man of small income of the greatest value. No money can represent the love and care which some parents give their children, and no money can represent the value of children in affecting the parents for good, and in holding together the elements of the social unit. Besides, children are the absolute necessity, no matter what they cost. With no children there would not be a living human being in 100 years.

If the average of all these curves in a nation showed less area above than below the zero line, we should expect such a nation soon to become mortgaged by another. In case the earnings represent a large drain upon natural resources, as is now the case in America, we may expect, in the future, decreased earnings, or hope for greater efficiency.

The curve shown in Fig. 5, so commonly exemplified by idle sons of rich Americans, imperfectly illustrates the economic value of such individuals. The really idle rich are not only worth nothing, but are really a serious detriment to a country. They create markets in order to satisfy purely selfish desires, which in turn seek new buyers of things not helpful. They divert human energy and capital into waste channels. They set a bad standard and example, which the poorer attempt to emulate. They create a dangerous environment in general to society.

There are people who assert that the birthday parties to cats, monkey dinners on horseback, and donkeyized pageants of extravagant and useless expenditure of money, *i. e.*, human energy, are good things because they give employment to the poor, when, as a matter of fact, really wasted human energy is a loss to the whole people. Some think, also, that extraordinary and idle extravagance acts as a stimulus to those out in the struggle for existence and holds up to them the reward that they too might enjoy if they could, or their fathers had,

wrecked a bank or a railroad, or obtained the monopoly of some necessity or luxury of life. **Waste in consumption is even a worse evil than inefficiency of production and distribution** because of the bad moral and educational effects which undermine the health and cause degeneration.

The one redeeming feature of the parasitic, or idle or incompetent rich, is that they are busy with their automobile appetites in redistributing the control of their wealth. We could be sorry for them, because they really are unfortunate, if there were not so many victims.

The robber, thief, gambler, political grafter, beggar, incompetent poor, and similar classes, might be shown up by curves like that of the idle rich, in that there are no earnings. These classes have practically no redeeming features. They are partially the result of conditions for which society is to blame and hence constitute an ailment of society, and if they are numerous or active enough, they keep society on the alert to locate and cure its defects.

In connection with Fig. 5, attention must also be called to the fact that there is a tendency on the part of the American man to make of his wife merely an idle advertisement of his success. So many of the things formerly necessary for a woman to make or do at home may now be ordered over the telephone. Even the children may be cared for in kindergartens and boarding schools. It is cheaper to have specialists do many things now to be done. One of the great problems of the immediate future is to find satisfactory spheres of activity for women, married and unmarried, because they, like men, must be kept busy,—not at killing time, but in using it on things that count for racial improvement.

In the case of the shop girl, Fig. 6, or of any individual receiving less than is necessary to spend, in the particular station in life, society pays the difference in various ways, and the cost to society is much more than the money difference between earnings and expenses. An applicant for a position in a department store, on saying that it was not possible to live on the salary offered, was told, "We don't expect you to."

Money-life curve No. 6 applies to such a case. Surely we should not place all the blame upon the average individual who fails to make his accounts balance and takes, in consequence, a devious course.

Relatively too small incomes, earnings, or wages, may be due to one or more of several causes, thus:

(*A*) Individual incapacity, unfitness, lack of proper training, and too many wants.

(*B*) Unfavorable conditions and competition.

(*C*) Unfair laws and traditions.

(*D*) High cost of living.

The first cause, (*A*), is generally due to faulty education. Training boys or girls till fourteen or eighteen to want things, and then letting them go out into life without the habit of supplying either their cultural or natural wants, is something of a failure. Training the few that they may live at the expense of the many, or that they should expect to do so, also ends in failure. This takes us right back to the reformation of the home, school, and community training until fourteen, and to fortbildung schools, for the masses, between the ages of fourteen and eighteen. Incapacity due to hereditary weakness can often be traced to faulty education received in some previous generation.

In regard to unfavorable conditions and competition, (*B*), reference need only be made to Germany, which has done so much, notwithstanding close competition, by means of education, while under natural conditions not nearly as favorable as in the United States.

As to unfair laws, (*C*), it should be enough to say that there is a sufficient number of voters in this country who know what a square deal is, to get it if they would vote for it. One hundred able and unselfish leading citizens could "clean up" a city, if they would. Wrongdoers are as vulnerable as they are active in their own selfish interests. If older people are hampered by the no-vote or careless-vote habit, the least they can do is to **habituate** the coming generation to voting while in school. Leader selection is a habit to be acquired while young.

The people are looking for unselfish experts who will have the same foresight in behalf of the masses that business managers have for their business. Business success does and always will depend upon selfish foresight. The masses have very little ability of this kind in any given direction. They learn by experience, after business foresight has already been rewarded. The education, selection, and supervision of leaders is evidently a part of the educational problem. The sentiment is growing that the public welfare demands that *those in power shall be honest, able and fit.* This applies to money power as well as to political power. There seems to be no reason why the public should pass and enforce such laws as will enable the parasitic and incompetent to exact a perpetual toll, without returning compensation for the protection and privileges of citizenship. The more power and wealth, the greater is the protection and opportunity provided by the State and enjoyed by the individual.

It cannot be expected that all voters shall have a sufficiently broad horizon to assist directly in making laws. It is nonsense to expect the common wage-earner or the plain business man to be an international diplomat. The most that can be done is to train the masses to select suitable and trained leaders who will act unselfishly in so far as the people they represent are concerned and thus regulate the tendency of all classes to shift the burdens to others.

Trained political leaders are now developed by the same method as that employed in training generals during the Civil War,—costly experience—when they should be given the preliminary training for statesmanship and politics as now given in law, medicine, engineering, etc. The old-time professional politicians have not, in general, been satisfactory, because their tenure of office depended upon certain selfish considerations which prevented unprejudiced action in behalf of the voters. Lawyers and business men, in general, especially the latter, can earn more in private business, so that there is little incentive for a successful business man to sacrifice his personal interests in order to hold a political office. At the present

time the choice of the people seems to be swinging towards educators or educational administrators because of their supposed unselfishness. Their ability in political fields, however, remains to be demonstrated.

Civil service examinations may be extended to cover more of the expert positions than now, and further, may be the means of selecting candidates for further training as a preparation for political or civil service. Universities may care for the preliminary part of this training.

High prices, (D), or high cost of living, can be shown to be very largely within the control of education. *By high cost of living is meant that the ratio of wants (necessities, needs and desires), expressed in dollars, to human mental and physical energy, also expressed in dollars, is high.* The money-life curves might have been plotted in terms of human energy instead of earnings, and wants instead of expenses.

The following outline, involving wants, supply, competition, waste, conservation, arbitrary control of prices, wages and pensions, should bring out the relations among high prices, education, and money-life curves.

I. **Wants** create the demands that practically determine values. Wants are the most important factor in the law of supply and demand because anything not wanted has no value, or is a detriment—of negative value. Future wants, represented by foresight, are connected with the probable future birth rate. Advertising is a form of selfish education intended to stimulate wants. Most of our wants are for luxuries and are an educational product, increasing with civilization. Educators must be extremely careful, therefore, not to educate the masses to want things, without at the same time providing the training which will enable these wants to be satisfied. If wants for luxuries are developed by school education and by community environment, then this demand will direct the expenditure of human energy and natural resources to supply these wants, and a relative reduction in the supply of necessities or natural wants will result. The consequent high prices bring a hardship to those just able to earn a living.

As an example, if we live in an automobile environment we acquire automobile wants and all the other little wants that go with the machine. Many exchange their future energy, by mortgaging a surplus as represented by homes, for automobiles. The human energy engaged in designing, building, selling, operating, repairing and supplying the accessory wants is diverted from raising potatoes and beef and wheat. High prices result. There are many other examples.

II. **Supply,** or production and distribution, in the majority of cases depends upon that intelligence and training which enables man to direct the forces in nature to his advantage. This factor is almost entirely within the control of the educational system, and while *wants,* in civilized life, depend largely upon the cultural, the **supply** depends more upon the success of the vocational system of education.

III. Fair **competition** is a great stimulus to low cost of production and distribution, because most people follow the lines of least resistance. They look for leaks when they must. Neither fair competition nor efficiency is possible without the very best forms of education. Pure food laws, and other laws preventing unfair competition, enable the decent business man to stay in business, and thus tend to lower prices, and not to raise them.

Political questions of this kind may not belong directly to grade schools, but they are connected directly with the education of adults. Real voters should be in constant attendance at the "Political University of the Republic," in which great and unselfish and incorruptible leaders are the lecturers, the daily and weekly publications are the text-books, and the community constitutes the laboratory. Unfortunately, the attendance, excepting in the laboratory, is at present very poor and some of the political lecturers have concealed axes of their own to grind which they often use to curtail the interests of the masses. The laboratory work is very poor because of the lack of high-priced, high-quality teachers.

IV. **Waste** is due to over-supply, to the maintenance of parasites, to lack of good training, and to general inefficiency in

production and distribution, and consumption. Misdirected human energy, misplaced surplus human energy as represented by money, and misused natural resources, make waste. If forests are cut down and not systematically replaced by young trees, the loss of the use of the natural forces involved in growth is a waste. Unused water power simply goes to raise the temperature of the stream below the falls.

Money itself is seldom lost. When a man "loses a fortune" it simply means, in most cases, that he is compelled to transfer power or control because of inability. Society is not the loser, except in so far as human energy and natural resources have been wasted or destroyed. Evidently waste, or loss reduces efficiency and increases prices. It is due largely to lack of education or to bad education in the home, school, and community.

The waste due to faults in production, even with the present inefficient schooling of the masses, is not large as compared to that due to wasteful or unnecessary consumption. The latter, in turn, is a very small factor when compared to the wasted nerve energy and loss of health and morals of those fit to survive, due to certain conditions which prevail especially in large cities. Degeneration is a waste and is worse than early death. It requires two strong soldiers to carry a wounded one. Evidently the training which will prevent this sort of waste must be given in the home, school, church, and community. Public morals and ideals are both the cause and the result of such training.

V. **Conservation** is a factor affecting, most particularly, future prices. The solution of the conservation problem involves foresight of the highest degree, and will be possible only after properly educating both the masses and the experts. At the present time the man in the street thinks of conservation as consisting in the prevention of "the trust" from obtaining control of a neighboring power-site, when as a matter of fact the trust might put electrical energy on the market that would otherwise go to waste. In so far as conservation itself is concerned, it does not matter whether it is practiced by the gov-

ernment, by trusts, or by individuals, as long as waste is prevented. If conservation involves monopoly, then an entirely different set of problems arises,—that of redistribution of wealth, graduated taxes, government control or ownership, socialism, etc. In any case, the rights of a trust or of an individual can exist only by the consent or because of the ignorance or indifference of the public.

The cause of or motive for wealth is human wants, very largely determined by education. The sources of wealth and resources to be conserved are as follows:

1. **People** may produce an increasing amount of human mental and physical **energy,** depending upon their health, ideals, and education.

2. **Country** (land, water and air), which may be increasingly and is perpetually productive. (Forests are reproducible; mines are exhaustible.)

3. **Forces of nature** which may be directed in the interests of man by machines.

4. Combinations of the above three factors, represented by the **manufactured property** and possessions of the people collectively and individually.

Conservation, and future prices, depend upon foresight which goes back to the personal experiences of childhood, which is an argument for experiences rather than school ideas only for children.

VI. **Arbitrary control of prices** generally results, in the end, in higher prices, because of selfishness and because of decreased incentive to efficiency in manufacture, and to a decreased rate of progress in the arts. The odium attached to the word "trust" results from the overwillingness to accept unearned remuneration, or aggressiveness in fighting for it,—a chronic form of selfishness which needs continual treatment.

The primary object for the organization of a trust is gain for the organizer. Following this comes the intention of increasing profits through increased economy in overhead expenses, production and distribution, in various ways which are entirely legitimate and fair. Another object, not so praise-

worthy, is to eliminate the uncertainties of business ventures by eliminating competition, thus making the trust a good paying investment with no risk. In regard to setting prices, many of the trusts merely wish the law of supply and demand to be allowed free operation, which enables the price to be regulated according to the wants of the buyer, and not according to cost of production and distribution.

In some cases, a gift or privilege of the people, made through their more or less honest, intelligent and trained representatives, has been capitalized so that the people pay perpetual toll on their own gift and according to another's estimate of its value. The result has been extremely objectionable to the victims. Large amounts of stock have been issued to or taken by the clever organizers for their services, upon which the public is forced to pay perpetual toll, as well as more or less unearned salaries, dividends on watered stock, and large profits with the elimination of the justifying business risks. The secondary effects—smothering of some forms of progress and the results to follow the tendency to make every man a hired man—are not yet greatly felt. But the perfect willingness on the part of the "bad trusts" to buy or coerce favorable laws and decisions has been seen and felt. The secondary results have not yet been fully realized but foresight prepares us for the worst.

The conditions which make trusts and monopolies possible are due to the modern progress in science which has made at the same time competition to become almost international. Science has multiplied the producing power of a man many times, has almost eliminated distance in so far as transmitting intelligence is concerned, making management at a distance possible, and has made distribution quick and cheap. The result has been a growing demand for duplicated necessities and luxuries manufactured in large quantities by specialists. No trust could exist without a monopoly of one or more of the elements entering into production or distribution, such as control of the materials, control of machinery, or control of the means of distribution or sale. By control is meant such advantage as enables the trust to drive out competition.

The forces effectively opposing the trusts and monopolies result from educating the individuals to form counteracting "trusts," labor unions, political parties, federalized trust legislation, and coöperative buying, selling, manufacturing, and loaning associations.

Interest is the price paid for the temporary use of the right or power to direct human energy. It is paid by those who expect to profit by the creation of a surplus, to those who confine their activities to insuring the safe return of the power loaned together with the interest. Interest rates are higher in Dakota than in Massachusetts, and higher in the United States than in Germany, since the uncertainties of rapid development make the risks and services of the loaner greater.

A sum of money placed perpetually at interest at a rate higher than that of other sums could, in time, draw all the money to itself. For this reason intrenched money power is just as dangerous to the safety of the republic as intrenched political power. Invariably these two forms of power are combined. The public must be educated to provide the opposing force, since without an equal and opposite force there will be movement which in this case would result in encroachment upon the rights of the masses.

With the exception, perhaps, of monopolies of the absolute necessities of life, no monopoly is more obnoxious than the **money-trust.** Specialization has gone to such an extreme that money has become an absolute necessity in order that specialized human energy may be readily exchanged for the large number of things necessary to civilized man. The day when a man labored for a day and returned home with his pay in food has passed. Few raise and make their own food and clothes. An exchange medium has become so necessary that we often confuse money with that which it stands for; so that a temporary withdrawal of large sums of money from circulation paralyzes business. We have become so accustomed to exchange human energy to supply our wants, measuring each in terms of the dollar unit, that the temporary loss of the standard creates more confusion than would the depriving retail stores of their sets of weights and measures.

A group of men who can suddenly decrease the amount of visible cash can create fear, doubt, and lack of confidence to the point where indispensable credit ceases to be acceptable instead of cash. Foresight immediately prompts many to curb their luxury, or unnecessary wants, which causes business to slow up, and the resulting idleness ends in a panic. The length of the unit, or the purchasing power of a dollar then becomes greater. If the larger part of credit were based on actual surplus instead of upon future producing power, and if our artificial wants were limited to the present satisfying power, panics could not be serious. Since both wants and the ability to satisfy them are within the control of education there seems to be good reason why the present ratio of vocational to cultural training should be increased.

The conditions brought about by the irrepressible tendency to centralize, as exemplified by trusts and monopolies, have arisen so suddenly that slowly forming public opinion has not had time to act. The masses are learning, however, from experience, that they have a problem to solve,—whether it is to be solved by socialism, government ownership, government control or regulation, or by dissolving the trusts, or by regulation of either the monopolies or competition, education must precede the correct solution.

Many explanations are given for the shortening of the dollar unit of measure,—more gold, larger wants and more of them, luxury wants, easy spending, poorer credit, relatively less rate of money circulation compared to the amount now required, etc.; but in any case the reader will see that education of the masses as well as of the leaders is the important factor.

The trust problem is an evidence that the people must have leaders and representatives of ability and foresight, and the greater the advance in knowledge and civilization the greater become the problems to be solved, and, hence, the greater the demand for education. Provision must be made for developing and selecting such leaders, and sufficient reward must be offered to induce the right kind of men to enter the

service of the public. If leaders cannot be found who can interpose a foresight that is equal to that of selfish business foresight, we shall have continual encroachment upon the rights of the masses, and a greater and greater problem of distribution of wealth and opportunity among those fit to use them.

VII. The wage problem is seen to be intimately connected with wants and education, efficiency and education, and political and money-power and education. It is a problem of creating more wealth to be divided by increasing efficiency in production and distribution, of providing a square-deal division of this wealth and, also, of increasing the efficiency of consumption. Great reward for great service must remain.

Specialization has made the subject of pensions and other provisions for earners of small wages of increasing importance. Pensions, as contrasted with charity, are based upon the supposition that workers, aided by natural forces, through the means of machinery, should be able during the period of middle age to supply the normal wants of a life-time and, further, that part of the surplus created by the worker should be cared for by those better trained to do so than is the average person.

No matter what phase of civilized life is studied, the good and bad conditions will be found intimately connected with the problem of education. The reason that education does not receive more or better attention is because of that lack of foresight which is itself a product of personal experiences and education, beginning in early youth.

(To be continued)

COLLEGE NEWS.

West Virginia University.—Professor E. N. Zern, formerly professor of coal mining at the University of Pittsburgh, was elected to fill the vacant chair in mining engineering, beginning his duties September 1, 1912. Professor Zern remained at The Pennsylvania State College as instructor for two years after graduation and has since had extensive experience in practical mining as mining engineer and mine superintendent. He was recently elected secretary-treasurer of the West Virginia Coal-Mining Institute. R. E. Seamon, for nine years instructor in wood-working at Cornell University, succeeded Mr. R. H. Chandler as instructor in woodworking and foundry practice. R. P. Davis was promoted from associate to full professor of structural and hydraulic engineering. —Professor F. L. Emory has completed his manuscript for rather an elaborate treatise on "Strength of Materials."—J. E. Hodgson, late of Baltimore Polytechnic Institute, and former president of Davis Elkins College, has been assistant professor of mathematics since the opening of the school year. —Assistant Professor John B. Grumbein has obtained a leave of absence for next year for the purpose of taking a graduate course elsewhere. His place will be filled by a temporary appointment.—During the summer vacation Dean C. R. Jones visited the Panama Canal Zone. The inspection of the canal was personally conducted by the West Virginia boys employed by the Canal Commission.—Options in hydraulic and highway engineering have been provided in the civil engineering course, and it has been decided to give the degree of B.S. in E.E. to those taking the electrical course instead of the bachelor's degree in mechanical engineering.—A school of mines has also been established which offers three years' work in practical mining of an elementary character and a six weeks' summer lecture and demonstration course for practical miners.

The equipment has been materially improved during the past year. The electrical laboratory has been greatly improved. Provision has been made for rescue work in mining and for laboratory facilities for testing road materials.

Worcester Polytechnic Institute.—Professor H. B. Smith, head of the department of electrical engineering, is attending lectures in London by Professor Sir James Dewar and Sir J. J. Thomson. Professor Smith will remain abroad during the remainder of the present school year.—The leading article in the January issue of the *Journal* of the institute was by L. P. Alford, '96, editor of the *American Machinist.* It is entitled, "The Present State of the Art of Industrial Management."—Professors A. W. French, H. C. Ives and C. M. Allen, attended the annual meeting of the American Society of Civil Engineers in New York. They formed part of the company that by invitation inspected the Grand Central Terminal and the Kensico Dam.—The trustees have purchased thirteen acres of land adjoining the present institute property on West Street. This makes about thirty-four acres of land now owned by the institute, and the new purchase will provide for growth for many years to come.—Acting President Conant and Professor Butterfield, of the department of mathematics, attended the recent reunions of the alumni associations in Buffalo, N. Y., Cleveland, O., Detroit, Mich., Chicago, Ill., and Pittsburgh, Pa.

One of the most important events of recent years to the Institute is the election of Professor Ira N. Hollis of Harvard University as President.

Ohio State University.—The winter course in highway engineering (February 24 to March 8), given this year for the first time, has proved to be popular with the engineers of Ohio who are engaged in highway construction. Contractors, inspectors and county commissioners to the number of sixty enrolled for the course. The Ohio Good Roads Federation cooperated with the university in meeting the expense. The lectures covered many phases of highway construction, main-

tenance and materials. Among the special lecturers were Professor A. H. Blanchard, of Columbia University; A. N. Johnson, state highway engineer of Illinois, and J. J. Voshell, U. S. highway engineer, Washington, D. C.

Johns Hopkins University.—The names of three of the men who are to direct the destinies of the new institute of technology were announced at the annual Founder's Day exercises, held on February 22. They were: Charles Joseph Tilden, now professor of engineering mechanics at the University of Michigan, to be professor of civil engineering; Carl Clapp Thomas, now professor of steam and gas engineering at the University of Wisconsin, to be professor of mechanical engineering; John Boswell Whitehead, now professor of applied electricity, to be professor of electrical engineering.

North Carolina College of Agriculture and Mechanic Arts.—A new $50,000 shop and laboratory building is to be erected and equipped for the mechanical department. The building will contain the machine shop, wood shop, forge shop, foundry and mechanical engineering laboratory. Later a new building will be erected for the drawing rooms, class rooms, offices, library, etc., of the department. Professor H. E. Satterfield, head of the department, will have general oversight of the building operations.

SECTION II

PAPER FORMING A PART OF THE PROCEEDINGS OF THE SOCIETY.

E.M.F. COMBINATIONS IN A SIX-CIRCUIT ALTERNATOR.

BY G. W. LAMKE,

Assistant Professor of Electrical Engineering,
Washington University, St. Louis.

In planning the laboratory course at Washington University, it has been our aim to parallel the lecture work on electrical machinery as closely as possible, and also to illustrate the theory of electrical machinery as well as the operating characteristics. One of the most interesting and instructive experiments illustrates the combinations of vectors.

The machine used in this experiment is rated as a 15 k.w., 3-phase delta, 220-volt alternator. It has 6 field poles and 36 armature slots, making 6 slots per pole. The armature winding consists of six independent open circuit windings, which are therefore 30 electrical degrees apart. The terminals of each winding are brought out to a terminal block on the frame of the machine and these terminals are carried to a marble tablet board in such a manner that the windings are represented as being 30 mechanical degrees apart in phase. An elevation view of this board is shown in Fig. 1. Each terminal wire is connected to two brass jacks by an appropriate lug on the back of the board. The heads of the jacks are set into counter sunk holes in the board, so that they come flush with the face of the board. Connections between jacks are made by flexible wire connectors terminating in split brass plugs, which are fitted with wooden handles.

With this arrangement it is possible to connect the machine as single-phase, two-phase, three-phase delta, or three-phase star.

In operation, the machine is driven at its rated speed, viz.: 1,200 R.P.M. by a direct current motor and its field is excited

so that each winding gives 100 volts. This does not give the rated voltage of the machine but facilitates the computations of voltages of the various combinations.

The students work in parties of three and each party makes each of the above named connections. Then the party draws a diagram of the vectors showing their phase relations and calculates the voltage which they expect to get. Then they measure the voltage to see if there is an agreement between calculated and observed values. As there necessarily must be a close agreement between observed and calculated values, the student can tell whether or not he has made a mistake.

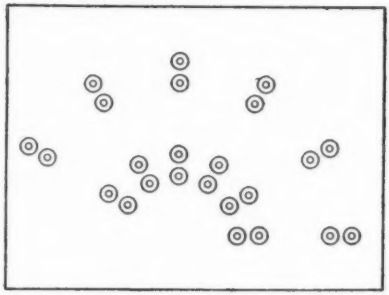


FIG. 1.

As the two machines of this type which we have in the laboratory are used for all alternator and synchronous motor experiments, each student becomes thoroughly familiar with the connections before his course is completed.

To connect the machine as a single phase generator, it is only necessary to connect all the windings in series: *i. e.*, the beginning or inside terminal of the first is connected to the end or outside terminal of the second and so on until all are connected together leaving two free terminals which are the terminals of the single phase circuit. The corresponding vector diagram is shown in Fig. 2, the voltage of each winding being 100. The value of the resultant, *M-O*, will be $[100 + 2(\cos 30°) \times 100] \times 2 \times \cos 45° = 396$ volts. This connec-

tion illustrates the necessity of considering breadth factor in the voltage equation of an alternator. Since the rated current per coil is 23 amperes the capacity of the alternator is $23 \times 396 = 9{,}000$ volt amperes.

The two-phase connections are made by connecting windings *a*, *b* and *c* in series, forming the resultant *M-N*, and *d*, *e* and *f* in series, forming the resultant *N-O* (Fig. 2). It is evident

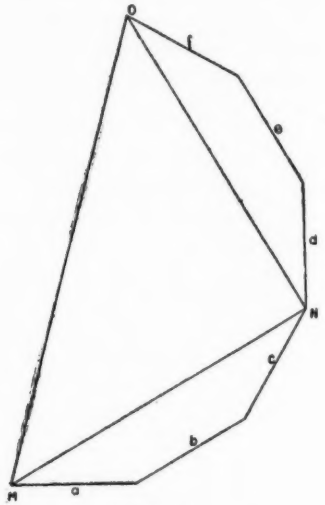


FIG. 2.

from the figure that the two resultants are at right angles. The value of the resultant in this case is 273 volts, the breadth factor therefore is larger than with the single-phase connection. The capacity of the machine is with this connection $273 \times 23 \times 2 = 12{,}500$ volt amperes.

The three-phase delta connection is made by connecting windings *a* and *b* in series, *c* and *d* in series, and *e* and *f* in series, giving the resultants *M-N*, *O-P* and *Q-R*, as shown in Fig. 3. Assuming that the outward direction from the center

is positive, a delta connection is made by connecting point Q to point N, point R to point P, and point O to point M, giving the figure shown in Fig. 4. The voltage per phase in this case is $100 \times \cos 15° \times 2 = 192$, which shows that the breadth

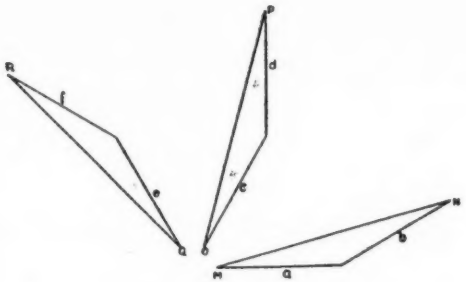


FIG. 3.

factor has still further increased. The capacity of the machine is $3 \times 192 \times 23 = 13{,}100$ volt amperes. It must be noticed that in traversing the delta, starting from MO and

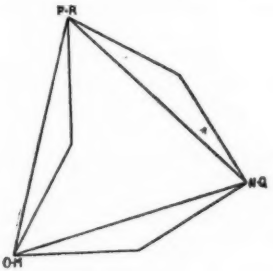


FIG. 4.

going in the direction of the arrow, MN and QR are traversed in the positive direction but PO is traversed in the negative direction. This part of the experiment illustrates the necessity for the reversal of one phase in a 3-phase machine.

The three-phase star connection is made by using the same combinations of vectors as for delta connection. For this connection, however, points *M, P* and *Q* are connected together and points *N, O* and *R* are the line terminals, giving the diagram shown in Fig. 5. This connection also illustrates the necessity for the reversal of one phase in a 3-phase machine. The capacity in this case is the same as before, but the line voltage is $192 \times \sqrt{3} = 333$.

FIG. 5.

There are other connections that may be used, for illustrative purposes, one of which is a combination delta star, or two deltas may be obtained from the one machine, etc.

The experiment, therefore, illustrates breadth factor, reversal of one phase in 3-phase machines and variation of capacity with the variation in the number of phases.